THURSDAY, JULY 12, 1877

THE " INFLEXIBLE "

THE question which has been raised respecting the stability of the *Inflexible*, important as it is with reference to that ship, leads to very much wider and more general considerations. It is already known that the same principle, or want of principle, which has brought doubt upon the one ship appears also in the *Ajax* and the *Agamemnon*, and is to be reproduced in the only ship of much size or importance which the Government purpose commencing during the present year. But even in this succession of large and costly ships we see probably but the beginning of a system which, having thus received countenance and sanction in the highest quarters in this country, may not improbably become extended over the navies of the world. We propose, therefore, to explain to our readers the nature of the question itself and the manner in which it has arisen.

And as an essential preliminary we will first explain what is meant by the terms "stability" and "curve of stability." For the purpose of this elementary explanation it will be sufficient to take the case of a ship floating in still water. In Fig. 1, which represents the transverse section of a ship taken through the centre of gravity, M represents the metacentre, G the centre of gravity, and B the centre of buoyancy, W L being the water-line when the ship is in an upright position. Supposing the ship to be inclined through an angle of θ degrees from that position by an external force, and W_1L_1 to become the new water-line ; she will now tend to return to the upright position with a righting force equal to her total weight or displacement, acting with the leverage of G Z, and therefore equal to W $\times$ G Z. This is obviously the case, because while the ship is held in the inclined position her weight will be acting downwards through G in the direction of G H, which is perpendicular to the water's surface, $W_1 L_1$, and her buoyancy, which may be supposed to act collectively through its centre of buoyancy, B_1, will be pushing upwards through the line B_1 M, and therefore the righting effect will be that of the two forces (weight and buoyancy, which are alike) acting at the opposite ends of the lever, G Z, as previously stated. It is equally certain that in all ordinary forms of ship G Z will be changed in length as the ship's angle of inclination is changed, and if we calculate its lengths for a series of angles, and set up the lengths so obtained as ordinates along a base line on which abscissæ are measured off to represent the angles of inclination, we can draw a curve line through the points so obtained, and thus form what is called a "curve of stability." The first instance on record of this being done for an actual ship or design is that given in a paper "On the Stability of Monitors under Canvas," read in 1868 at the Institution of Naval Architects, and published in their *Transactions*, and in several other places. After stating the amount of stability which certain rigged monitors would have under given conditions, and showing that the maximum stability, and even the vanishing stability was reached in them at moderate angles of inclina-

tion, Mr. Reed said : " It must be obvious that the danger to be apprehended by these monitors when under canvas is very great ; and when we think that they are liable at any moment to be overtaken by sudden gusts of wind, and that if they are heeled over beyond 8 deg. or 10 deg., the further they go the less resistance they offer to being capsised, their unfitness to carry sail must be quite evident."

The curve of stability was next constructed in the case of the *Captain*, immediately before her loss, and from a report by Mr. Barnes, one of the present Admiralty constructors, we take the following :—" We assume that the side plating on the poop and forecastle has been so damaged that the ship may be considered a rigged monitor with a free-board of about 6 ft. At that draught (25 ft. and $\frac{1}{2}$ an inch) with an inclination of 14 deg., the gunwale on the immersed side is level with the water, but the stability of the ship notwithstanding goes on increasing until an inclination of 21 deg. is reached. As Mr. Reed has pointed out in his paper (quoted above) on rigged monitors, with a pressure of canvas which would incline the ship to say 8 deg., the inclination of the ship to the surface of the wave may reach about 34 deg. (in this case) before the ship would upset. As this angle is large we do not consider that even with the sides of the poop and forecastle destroyed, the *Captain* would be unsafe."

The above cases are both those of rigged ships, which the *Inflexible* can scarcely be considered, although it must be acknowledged that, as designed, she carried a considerable spread of canvas on two masts, and the present proposals—which we understand have been made—to diminish the spread of sail at all times, and to do away with it altogether in war time, are no doubt consequences of recent discoveries respecting the stability, or want of stability, of the ship with the unarmoured ends badly injured. After what has passed, however, we must accept the *Inflexible* as a mastless ship in time of war, and therefore a ship which can do with less stability than rigged ships require. In order to illustrate the nature and character of these curves we copy, in Fig. 2, a figure from Mr. Thearle's valuable work on " Theoretical Naval Architecture,"[1] in which he has grouped half-a-dozen curves which may be regarded as types of various kinds of curves of statical stability which occur in practice, viz. :—

A. A lofty-sided troop-ship, carrying sail.
B.   Do.   Do.
C. A broadside iron-clad frigate, Do.
D. A turret-ship with high freeboard, Do.
E. A low freeboard iron-clad gun-vessel, not carrying sail.
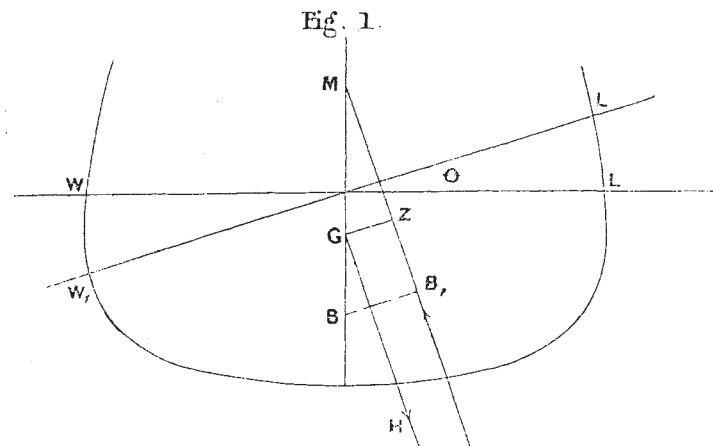*F.* A breastwork monitor, Do.

To facilitate comparison, we have added to Fig. 2 dotted lines showing the stability of the *Captain* as ascertained at the Admiralty just before her loss. The curve marked *a* shows the stability when the ship is fully stored and provisioned, and with the proper complement of coals on board with the poop and forecastle water-tight and assisting stability. The curve *b* refers to the ship under the same conditions, except that the poop and forecastle are supposed to be so damaged as not to assist stability. It will be observed that although Mr. Barnes considered

[1] Published by Collins, Sons, and Co., in the "Advanced Science Series."

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the ship safe even when she had only the stability shown by *b*, the ship actually capsised when she had the larger amount shown by curve *a*, the two curves being the same up to about 20 deg. of inclination, but the latter showing much greater stability both in amount and in range after that amount of inclination was passed. Mr. Barnes no doubt expected that the ship would never be pressed under canvas enough to endanger her, but the event
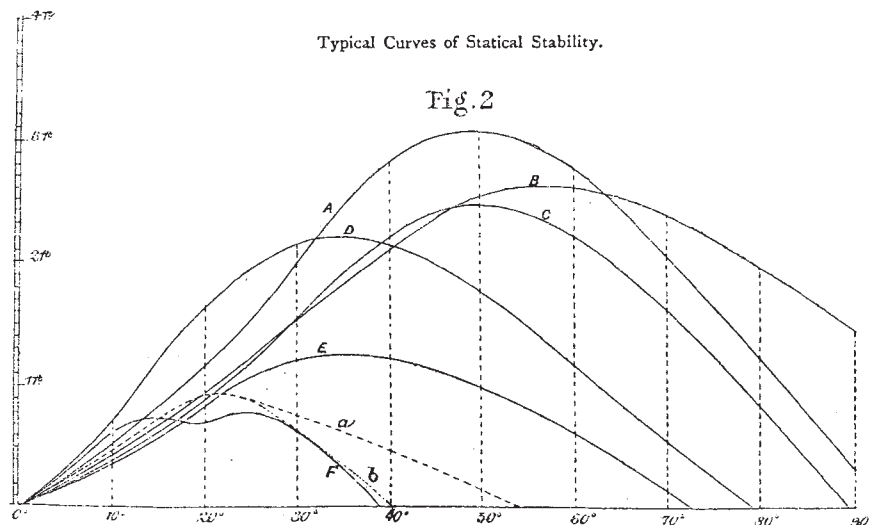

Fig. 1.

showed that in matters of this kind the measure of safety must be ample, and that we must not trust to the chapter of accidents for the security of our men-of-war against capsising.

We are now in a position to explain the case of the *Inflexible* up to the point at present attained in the discussion, but in order to understand it the reader must take clearly into his mind certain differences between her

Typical Curves of Statical Stability.

Fig. 2

and all previous ships as regards the relations of the armoured and unarmoured parts. In the case of the *Captain* we had a ship with armour rising to a uniform height of six feet above the water from stem to stern, and above this armour at one end a forecastle and at the other end a poop, both of these being of thin iron and unarmoured. It was in view, no doubt, of these unarmoured ends being liable to be so injured in action

as to contribute nothing to the ship's stability that the Admiralty officers calculated and stated (as above quoted from Mr. Barnes' report) the ship's stability with the poop and forecastle destroyed. But the reader should carefully observe that as these unarmoured ends were wholly situated in the *Captain* at a height of six feet above the water, their destruction to any extent whatever could not affect the ship's stability at small angles of inclination; and in point of fact by looking at the dotted curves in Fig. 2 we see that the stability is the same whether these ends exist intact or not up to an angle of about 22 deg., for up to that point the two curves are identical. At that angle of inclination the poop and forecastle enter the water, and the curve of stability declines much more rapidly when they are injured than when they are uninjured. In the cases of the *Devastation*, *Thunderer*, and some other ships, there was a different arrangement, and one less favourable to stability, for in them the forecastle (not the poop) was sunk, so to speak, down into the armour, so as to reach to within a foot or two of the water's surface. In such cases, of course, the curve of stability, with the unarmoured ends injured, begins to decline earlier than if the forecastle stood wholly above the armoured side as in the *Captain's* case; but the *Devastation* class are all unmasted ships, and therefore subject to no pressure of canvas, so that much less stability was required in them than in the *Captain* and other rigged ships.

The *Inflexible* class of vessels differ from all the ships previously named in a very marked manner, for in her the ends are entirely unarmoured (excepting as regards a horizontal deck lying seven feet below water), and while the forecastle, and poop, where it exists, in the other ships named are comparatively short, in her they occupy two-thirds the length of the ship—one-third at each end. The central part of the ship, one-third in length, is alone armoured with side-armour, and therefore in considering the stability during an action, we may suppose that two-thirds of the ship's length, viz., the two wholly unarmoured ends, are destroyed, destroyed that is in the sense in which Mr. Barnes obviously used the phrase in the case of the *Captain*; or, in other words, so broken and damaged by shot or shell as to let the sea flow freely in and out of them, and therefore to possess no stability to help in keeping the ship upright. In Figs. 3 and 4 we have, illustrated, the *Inflexible* injured in this manner. One of the contentions of the Admiralty is that these ends cannot be injured during an action to this extent; but whatever the Admiralty officers may now

assert in this respect, it is clear that in the case of the *Captain*, they thought this amount of injury possible, and it is equally clear from the quotations given by Mr. Goschen in Parliament, that they thought the same of the *Inflexible*, when they proposed that she should be built, and thought this, notwithstanding the introduction of certain cork-filled chambers and other sub-divisions upon which they now seem disposed to rely for the ship's safety. We may add that even during the present controversy, Mr. Barnaby has published figures which assume the total annihilation of the ends, and if they can be totally annihilated it is clear they may be so far injured as to lose all buoyancy and stability. We may confidently assume, therefore, that the ends can be so far wounded and damaged as to cease to help the ship's stability, and therefore to leave her wholly dependent upon the citadel for the power of keeping from capsizing. In Fig. 3 we have shown several large injuries, such as we may assume modern shells are fully capable of inflicting, merely to help the reader to get clear ideas on the subject.

The question now at issue really is, therefore, what amount of stability has the ship (by virtue of the citadel) with the ends thus injured ? The *Times* and Mr. Reed say that careful calculations which have been made show that she has none, or next to none. Hitherto the Admiralty have refrained from saying how much they claim for her. They say that the *Times* and Mr. Reed are entirely wrong in their calculations, and that the ship really has abundant stability for all purposes of safety, and they appeal to a model which is at the Admiralty to prove this. Let us say at once no model can possibly prove anything of the kind ; the model must be weighted and arranged entirely to represent the results of calculations, and it is these results which should be clearly, and fully, and authoritatively stated. The Government have laid certain papers on the table of the House of Commons, but they are not yet published, and until they are in our hands it is impossible to pursue the subject further. We shall hereafter give due consideration to them. All that we can now say is that with the *Captain* case fresh in our memory, in which the Admiralty office dangerously
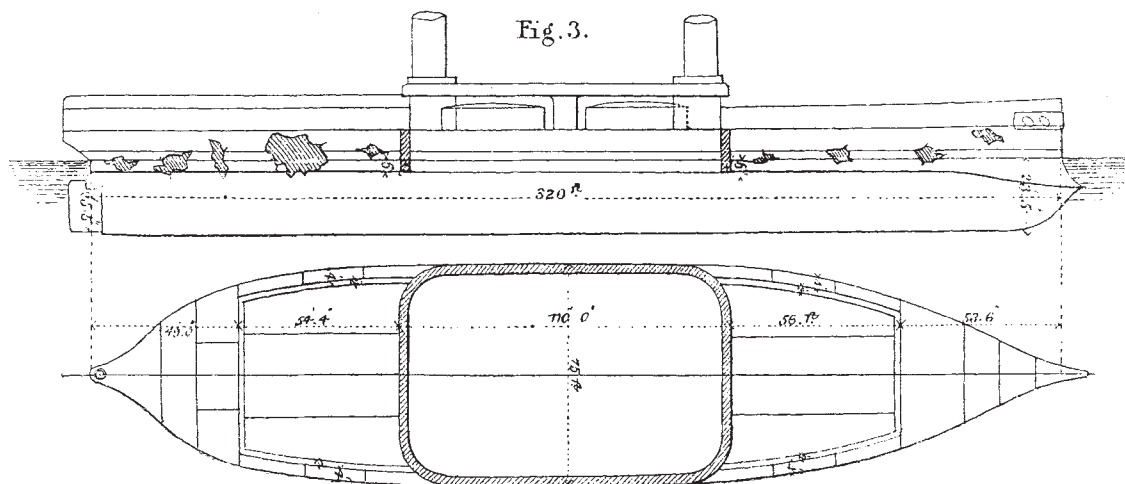

Fig. 3.

Fig. 4.

overrated the safety of the ship in this very respect, and, remembering as we do that for a ship to be safe at sea, she should have a very large margin of stability over and above that which mere statical and smooth water conditions point to, we shall not ourselves be satisfied with less than the Committee on Designs laid down, viz., " that the angle of vanishing stability should not be fixed at less than 50 deg." Nor shall we be content with this if this range is obtained only in conjunction with a small amount of stability from point to point. Mr. Reed has pointed out, in his letters to the *Times*, the great danger of considering range only, and has attacked the dictum of the Committee on this ground. Dr. Woolley, one of ts scientific members, has replied, admitting the accuracy of Mr. Reed's view, but explaining that the truth he enunciates is so elementary and obvious that the Committee thought it unnecessary to mention it, and would indeed have considered it " impertinent " (in the proper sense of the word) to state it. It is difficult to take this view of the matter, however, when we remember that the highest scientific officer of the Admiralty, in a matter affecting the

safety of four of H.M. ships of the largest and newest type, has seized this dictum of the Committee as a sufficient and satisfactory guarantee of their security. We fear we must conclude that the Committee either neglected a very serious element in the calculations, or else greatly overrated the skill and discernment with which their words would be interpreted.

THE DEVELOPMENT OF THE OVUM [1]

Bütschli on the Earliest Developmental Processes of the Ovum, and on the Conjugation of Infusoria.

Studien über die ersten Entwicklungsvorgänge der Eizelle, die Zelltheilung und die Conjugation der Infusorien. Von O. Bütschli. (Frankfurt, 1876.)

II.

COMING now to the large and important question of the *Conjugation of Infusoria*, its nature and bearing upon the life-history of the forms, we are bound to state at once our conviction of the inefficiency of the observa-